
UNIVERSITI SAINS MALAYSIA

Second Semester Examination
Academic Session 2003/2004

February/March 2004

IEK 103/3 – UNIT OPERATIONS I

Duration : 3 hours

Please check that the examination paper consists of **EIGHT (8)** printed pages before you commence this examination.

Answer FIVE questions only. Students are allowed to answer all questions in English OR Bahasa Malaysia OR combinations of both.

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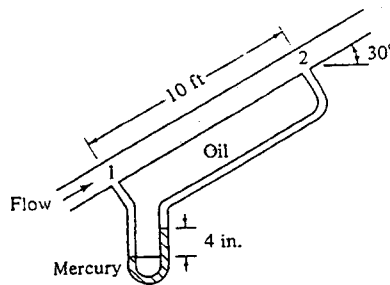
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1. (a) Water flows through a pipe of 0.15 m diameter fitted with an orifice meter of 0.10 m diameter. A vertical manometer is fitted across the orifice meter. The manometer fluid is mercury of specific gravity 13.6. Water fills the arms of the manometer. The reading of the manometer is 0.254 cm. If the coefficient of the orifice can be taken as 0.60, what is the volumetric flow rate of water at 15.56 °C ? The density of water at 15.56 °C is 999.0 kg/m³.

(70 marks)

- (b) A manometer is fitted on to a pipeline as shown below. An oil of specific gravity 0.9 flows in the pipe. The manometer fluid is mercury (S.G. = 13.6), and the manometer reading is 4.0 in. What is the value of $p_1 - p_2$?

(30 marks)



2. A horizontal steel pipe has a diameter of 0.0526 m and a length of 30.48 m. The pipe roughness is $k = 0.000045$ m. A fluid of density 1200 kg/m³ and viscosity 0.01 N.s/m² flows in the pipe at a rate of 9.085 m³/h. Calculate
- pressure drop, in N/m²;
 - power required for the flow.

(100 marks)

3. (a) A tank is filled with a fluid of viscosity 0.08 N.s/m² and density 975 kg/m³. The tank is without baffle. A 6 flat-blade turbine of diameter 0.15 m rotating at 18 rps is fitted in the tank 0.15 m from the bottom. What power is required for the operation ?

(50 marks)

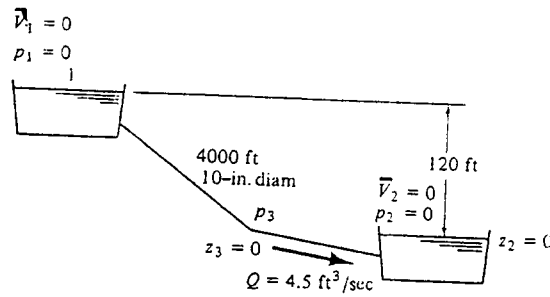
- (b) Two open water reservoirs as shown are connected through a smooth pipe of 10 in diameter and 4000 ft long. The water level in the upper tank is 120 ft above that of the lower tank. The volumetric flow rate is 4.5 ft³/s at 70 °F. Calculate

- the friction loss for the system;
- What is the value of the pressure p_3 ?

(50 marks)

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4. A liquid of density 63.5 lb/ft^3 and viscosity 1.35 cP is pumped through a steel pipe of 2 in diameter to the top of a storage tank open to the atmosphere. The volumetric flow rate of the liquid is 120 gal/min . The discharge of the pipe is 60 ft above the pump and the equivalent length of the steel pipe from the pump to the tank is 175 ft . If the pressure at the suction of the pump is 20 lb/in^2 , and the pump efficiency is 65% , calculate
- the brake horsepower of the pump;
 - pressure at the discharge of the pump;
 - If the electrical energy cost is 7 cent for every kWh (kilowatt-hour), what is the energy cost for pumping the liquid per day ?

(100 marks)

5. Consider the heat transfer by natural convection between a hot (or cold) vertical plate with a height of L at uniform temperature T_w and a surrounding fluid that is cooler (or hotter) with a uniform temperature T_a . The local heat transfer coefficient h_x at a height x is proportional to the local temperature difference between the plate and the fluid: $h_x = (dq/dA)/(T_w - T_a)$. It is found that the following physical factors are involved in the process:

$$f(h_x, x, k, C_p, \rho, \mu, \beta, \Delta T, g) = 0$$

With the use of Buckingham Theorem, obtain the relation among the above variables.

The dimensional matrix is as follows:

	h_x	x	k	C_p	ρ	μ	β	ΔT	g
\bar{M}	1	0	1	0	1	1	0	0	0
\bar{L}	0	1	1	2	-3	-1	0	0	1
\bar{t}	-3	0	-3	-2	0	-1	0	0	-2
\bar{T}	-1	0	-1	-1	0	0	-1	1	0

(100 marks)

...4/-

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6. (a) A horizontal venturi meter of throat diameter 2.50 cm is fitted to a pipeline of diameter 7.82 cm. Water at 26.67 °C flows through the pipeline. Mercury (S.G. = 13.6) manometer is used. If the manometer reading is 39.0 cm, what is the mass flow rate, in kg/s ? If 10% of the differential pressure is lost, what is the power consumption of the meter ?

(60 marks)

- (b) Oil ($\rho = 900 \text{ kg/m}^3$ and $\nu = 2 \times 10^{-4} \text{ m}^2/\text{s}$) flows in a smooth 5 x 5 cm square duct at an average velocity of 4.0 m/s. What is the pressure drop in 25 m long of the duct ?

(40 marks)

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CONVERSION FACTORS AND CONSTANTS OF NATURE

To convert from	To	Multiply by†
acre	ft ²	43,560*
	m ²	4046.85
atm	N/m ²	1.01325 × 10 ⁵
	lb _f /in. ²	14.696
Avogadro number	particles/g mol	6.022169 × 10 ²³
barrel (petroleum)	ft ³	5.6146
	gal (U.S.)	42*
	m ³	0.15899
bar	N/m ²	1 × 10 ⁵
	lb _f /in. ²	14,504
Boltzmann constant	J/K	1.380622 × 10 ⁻²³
Btu	cal _{IT}	251.996
	ft-lb _f	778.17
	J	1055.06
	kWh	2.9307 × 10 ⁻⁴
Btu/lb	cal _{IT} /g	0.55556
Btu/lb-°F	cal _{IT} /g-°C	1*
Btu/ft ² -h	W/m ²	3.1546
Btu/ft ² -h-°F	W/m ² -°C	5.6783
Btu-ft/ft ² -h-°F	kcal/m ² -h-K	4.882
	W-m/m ² -°C	1.73073
	kcal/m-h-K	1.488
cal _{IT}	Btu	3.9683 × 10 ⁻³
	ft-lb _f	3.0873
	J	4.1868*
cal	J	4.184*
cm	in.	0.39370
	ft	0.0328084
cm ³	ft ³	3.531467 × 10 ⁻⁵
	gal (U.S.)	2.64172 × 10 ⁻⁴
cP (centipoise)	kg/m-s	1 × 10 ⁻³
	lb/ft-h	2.4191
	lb/ft-s	6.7197 × 10 ⁻⁴
cSt (centistoke)	m ² /s	1 × 10 ⁻⁶
faraday	C/g mol	9.648670 × 10 ⁴
ft	m	0.3048*
ft-lb _f	Btu	1.2851 × 10 ⁻³
	cal _{IT}	0.32383
	J	1.35582
ft-lb _f /s	Btu/h	4.6262
	hp	1.81818 × 10 ⁻³
ft ² /h	m ² /s	2.581 × 10 ⁻⁵
ft ³	cm ³ /s	0.2581
	cm ³	2.8316839 × 10 ⁴
	gal (U.S.)	7.48052
ft ³ -atm	L	28.31684
	Btu	2.71948
	cal _{IT}	685.29
	J	2.8692 × 10 ³
ft ³ /s	gal (U.S.)/min	448.83
gal (U.S.)	ft ³	0.13368
	in. ³	231*
gravitational constant	N-m ² /kg ²	6.673 × 10 ⁻¹¹
gravity acceleration, standard	m/s ²	9.80665*
h	min	60*
	s	3600*
hp	Btu/h	2544.43
	kW	0.74624
hp/1000 gal	kW/m ³	0.197
in.	cm	2.54*
in. ³	cm ³	16.3871
J	erg	1 × 10 ⁷
	ft-lb _f	0.73756
kg	lb	2.20462
kWh	Btu	3412.1
L	m ³	1 × 10 ⁻³
lb	kg	0.45359237*
lb/ft ³	kg/m ³	16.018
	g/cm ³	0.016018
lb _f /in. ²	N/m ²	6.89473 × 10 ³
lb mol/ft ² -h	kg mol/m ² -s	1.3562 × 10 ⁻³
	g mol/cm ² -s	1.3562 × 10 ⁻⁴
light, speed of	m/s	2.997925 × 10 ⁸
m	ft	3.280840
	in.	39.3701
m ³	ft ³	35.3147
	gal (U.S.)	264.17
N	dyn	1 × 10 ⁵
	lb _f	0.22481
N/m ²	lb _f /in. ²	1.4498 × 10 ⁻⁴
Planck constant	J-s	6.626196 × 10 ⁻³⁴
proof (U.S.)	percent alcohol by volume	0.5
ton (long)	kg	1016
	lb	2240*
ton (short)	lb	2000*
ton (metric)	kg	1000*
	lb	2204.6
yd	ft	3*
	m	0.9144*

† Values that end in an asterisk are exact, by definition.

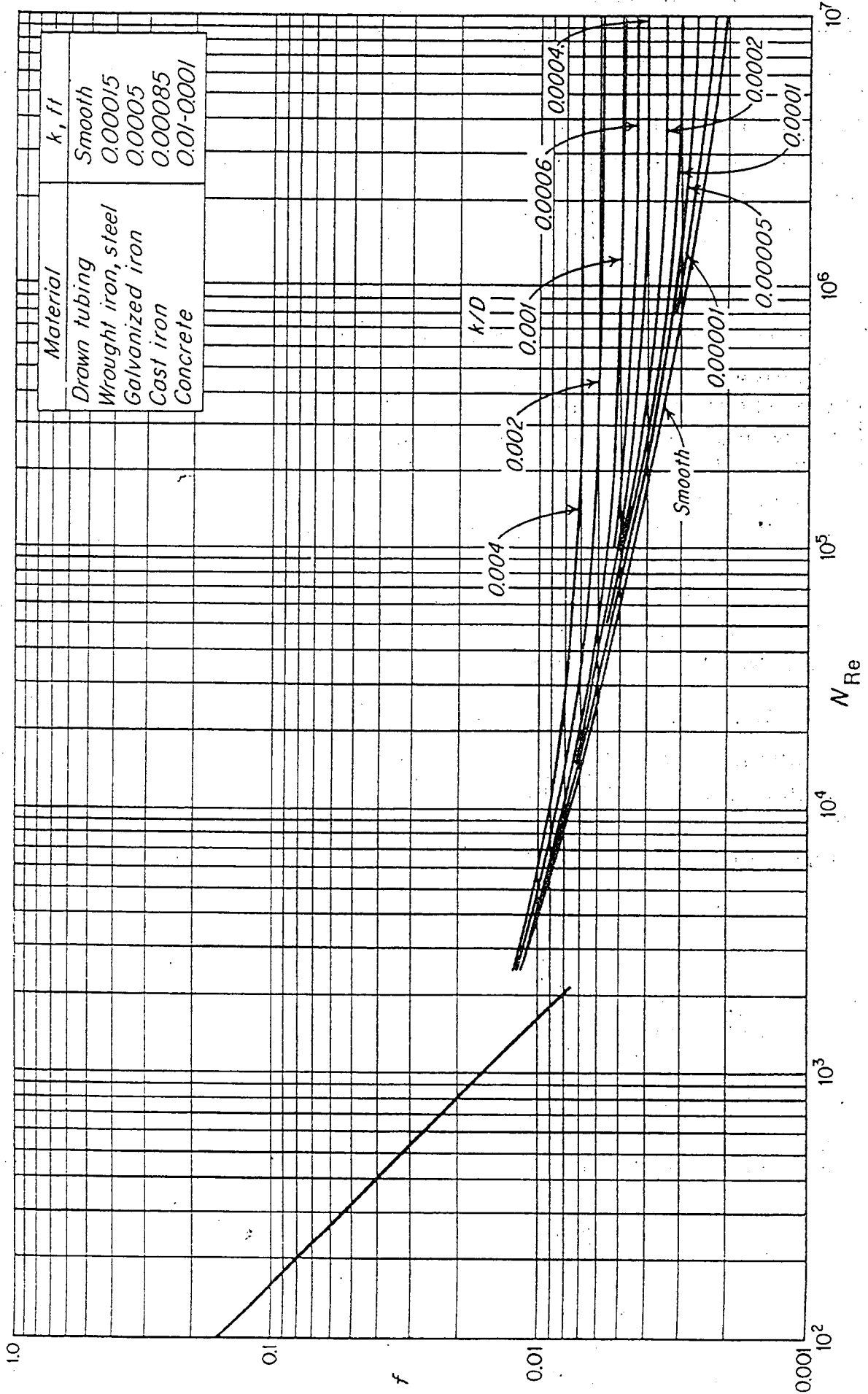


FIGURE
Friction-factor chart.

PROPERTIES OF LIQUID WATER

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Temperature T , °F	Viscosity† μ , cP	Thermal conductivity‡ k , Btu/ft-h-°F	Density§ ρ , lb/ft³	$\psi_f = \left(\frac{k^3 \rho^2 g}{\mu^2} \right)^{1/3}$
32	1.794	0.320	62.42	1,410
40	1.546	0.326	62.43	1,590
50	1.310	0.333	62.42	1,810
60	1.129	0.340	62.37	2,050
70	0.982	0.346	62.30	2,290
80	0.862	0.352	62.22	2,530
90	0.764	0.358	62.11	2,780
100	0.682	0.362	62.00	3,020
120	0.559	0.371	61.71	3,530
140	0.470	0.378	61.38	4,030
160	0.401	0.384	61.00	4,530
180	0.347	0.388	60.58	5,020
200	0.305	0.392	60.13	5,500
220	0.270	0.394	59.63	5,960
240	0.242	0.396	59.10	6,420
260	0.218	0.396	58.53	6,830
280	0.199	0.396	57.94	7,210
300	0.185	0.396	57.31	7,510

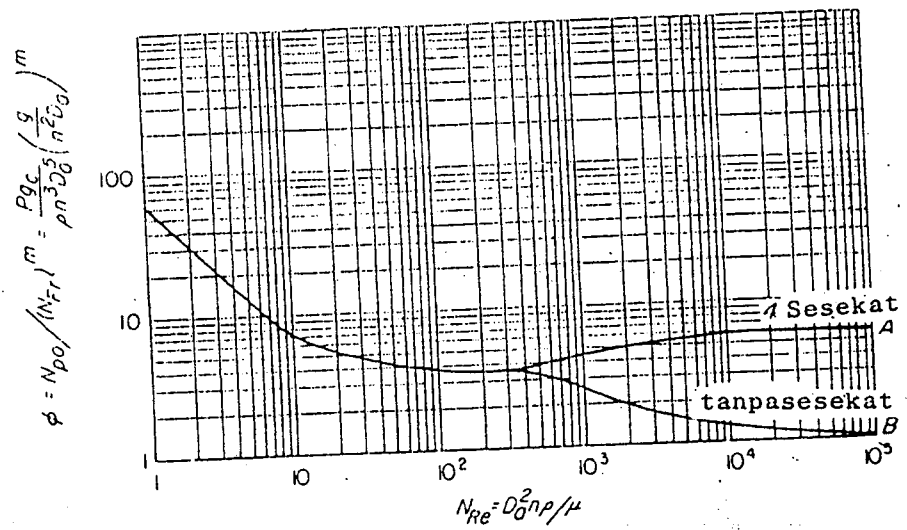
† From *International Critical Tables*, vol. 5, McGraw-Hill Book Company, New York, 1929, p. 10.

‡ From E. Schmidt and W. Sellschopp, *Forsch. Geb. Ingenieurw.*, 3:277 (1932).

§ Calculated from J. H. Keenan and F. G. Keyes, *Thermodynamic Properties of Steam*, John Wiley & Sons, Inc., New York, 1937.

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$$S_1 = D_t/D_a$$

$$S_2 = E/D_a$$

$$S_3 = L/D_a$$

$$S_4 = W/D_a$$

$$S_5 = J/D_t$$

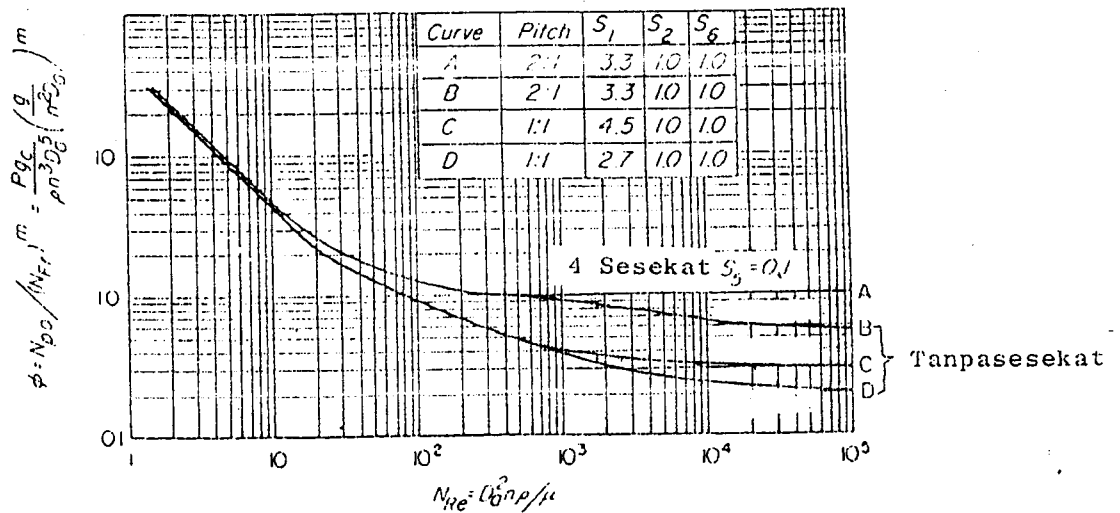
$$S_6 = H/D_t$$

Rajah Fungsi kuasa ϕ lwn N_{Re} bagi turbin 6 bilah.

Jadual Pemalar a dan b.

Fig.	Line	a	b
9-14	B	1.0	40.0
9-15	B	1.7	18.0
9-15	C	0	18.0
9-15	D	2.3	18.0

$$m = (a - \log N_{Re})/b$$

Rajah Fungsi kuasa ϕ lwn N_{Re} bagi propeler 3 bilah